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# Appraisal of Vernacular Building Materials and Alternative Technoligies for Roofing and Terracing Options of Embodied Energy in Buildings

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**Abstract:**

Nearly two million residential building are built annually in India apart from the offices, commercial and industrial buildings with demand and supply which is increasing year by year. It is essential to conserve the conventional energy by developing energy efficient buildings. Environmental quality and conservation of fossil fuels may become important in the context of limiting of GHGs emission and also reducing cost of materials. The most important stages from point of view of energy intensity: (a) Raw material acquisition; (b) Preparation & Manufacturing ;(c) Transportation But this paper broadly considered to analyze the first two parts as the third part of transportation energy vary from location to location, however it has been emphasized in the literature that 1 MJ/ tonne /km (diesel) for transporting materials can be integrated for location specific analysis. Besides, Energy estimates given in the literature for various materials such as the Cement 5.85MJ/kg, lime 5.62MJ/kg, LP 2.33MJ/kg (lime 30%, Pozzolana 60% and 10%calcined gypsum), steel 42MJ/kg, Al 236.8MJ/kg, Glass 25.8Mj/kg, Burnt clay brick 4.25MJ, Hollow block 12.3-15MJ, etc have been considered for energy appraisal. It is focused on some issues pertaining to Embodied Energy savings by identifying a few appropriate options for important building components and a comparison of energy in different types of roof and terracing has been made. Energy in different options of alternative systems have been discussed and compared with the energy consumed in conventional specifications to appreciate the consumption of energy in various materials for selection of appropriate materials with reference to energy savings and sustainable development.

**Key words**: embodied *energy, roofing, terracing and floorings, alternative technology, local materials, energy savings and sustainable development.*

## 1.0 Introduction

The production of advanced and novel-building materials with respect to the embodied energy

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consumption profile was emphasized by Mullick (1992) using the industrial wastes with reference to the source and its availability per annum for effective utilization in building industry. It has been elaborated by Kumar *et al.,* (1998), that the energy conservation and savings by using Fly ash sand lime bricks, hollow blocks and Lime gypsum bricks. Reddy *et al* (2001) classified the Embodied energy in three categories. 1) Energy consumed in production of basic building material; 2) Energy needed for transportation of building materials, and 3) Energy for assembling of various materials to form the buildings. The life cycle costing of PVC building materials and embodied energy have been analyzed by Mathur (2001). Pablo Zapata *et al* (2005) emphasized the energy savings in usage of Asphalt and Reinforced Concrete pavement Materials and construction. Kofoworola et *al* 2009, has analyzed the Life Cycle Energy Assessment of a Typical Office Building in Thailand to appraise the energy consumption critically to conserve the conventional energy. Chel et al (2009) published his study in Applied Energy on thermal performance and embodied energy analysis of a passive house: Case study of vault roof mud-house in India, applied Energy. The importance of embodied energy has been increasing as it consumes enormous quantum of energy in building industry. Hence it is essential and crucial to explore various ways and means to conserve precious conventional energy with due consideration to the $CO_2$ emissions, environmental quality and climate change.

## 2.0 Basic Paradigms of Ecological architecture:

Fly Ash is produced nearly 100mt annually has occupied nearly 75,000 acres for past 30 years – can be blended with cement up to 40%. Recent research indicates that the recycled plastic or post-industrial waste can be used as excellent insulating materials for flooring and roofing. Use of municipal solid and C&D (construction and Demolition) waste can be explored as a building material in construction Industry. Besides, Alternatives to cement & concrete include masonry cement, blast furnace slag cement, fly ash cement and fibre-reinforced composite cement can be utilised for construction. Light-weight, weather resistant and rigid, sisal based composite panels with polyester resin which can be used for wall partitions. Organic materials can be used for wood composites and coir based boards and tiles.

### 2.1 Alternative Technologies:

The vernacular concepts and its improvisation against a possibility of alternative technology due consideration to environment and cost - effective options that while ensuring good and efficient construction also leaves you with a substantial saving. This paper has been focused to have understanding about the energy efficient construction or alternative technology taking due consideration to vernacular and cost effective solutions.

#### 2.1.1 Core unit slabs:

Core unit slab is a precast hollow type slab of pre-stressed concrete generally used in multi-storeyed or in mass construction projects. Precast concrete popularity is linked with low-seismic zones and more economical constructions because of fast building assembly, lower self weight (less material) etc. The concrete slab has tubular voids extending full length of the slab , typically with a diameter equal to the 2/3 – 3/4 of the slab to make the slab lighter and reduces the transportation and material cost. The precast concrete I-beam between the holes contains the steel wire rope that provides bending resistance to bending momentum from loads.

#### 2.1.2 Jack arch:

Most of the flat roof vernacular building of India is Jack arch Roof construction with brick or lime concrete. The arch is supported on the lower flange of mild steel joists (RSJs). The steel joists are supported at their ends on the walls or on the longitudinal girders. They are spaced at a distance of 1000mm to 1500mm centre to centre. The elevation of the arch is kept equal to 1/12th of the span. Layer of concrete layer of 150mm is then poured over the roof to straighten the roof. Due to the super-imposed load on the arch, tension develops at the ends of the arch. To have increased span Steel tie rods can be placed at the ends of an arch with a suitable spacing up to 2500mm.

### 2.1.3 Filler slabs:

Filler slabs technology proved to be cost – effective roofing system which is based on the concrete portions replaced by the filler materials such as bricks, terracotta tiles, cellular concrete blocks and packed mud blocks. The principal behind the filler slab / roof is that upper part of the slab subjected to compressive and lower part for tensile forces. The lower tensile region dose not requires concrete except for holding steel reinforcement together , hence the compression portions at lower level can be replaced by filler materials.
The filler slabs also result in fewer loads getting transferred on columns / load bearing walls and foundation. The filler materials can be designed to generate air gap to work as good insulator especially top floor to reduce heat transmittance in addition to its thermal properties such as conductivity, density and specific heat.

### 2.1.4 Precast channel units:

It is easy to construct a roofing/flooring with an effective saving in cost and time. These units are reinforced cement concrete elements channel shaped in section and 2.5 to 4.2m long. The most commonly used precast slabs are the channel , double-T and tongue-and-groove types. The channel slabs vary in size with a depth , ranging from 230 to 300 in., width 600 to 1500mm, and a thickness of 25 to 50mm. It can be designed spans up to 15000. The double-T slabs vary in size from 1200 to 1800mm in width and 3000 to 6000mm in depth. The tongue-and-groove panel vary extensively in size, according to the design requirement. They are placed in position much like tongue-and-groove lumber; that is, the tongue of one panel is placed inside the groove of an adjacent panel. They are often used as decking panels in large pier construction. Matching plates are ordinarily welded and used to connect the supporting members to the floor and roof slabs.

### 2.1.5 Mud-phuska terracing:

One of the conventional ways of waterproofing is Mud-phuska terracing with tile paving. This method is equally suitable to hot as well as arid regions and is commonly used over RCC roofing. The procedure is to clean the RCC slab of dust and loose material there after spread hot bitumen at 1.70 kg bitumen per square metre. Immediately spread a layer of coarse sand over hot bitumen at 0.6 $m^3$ of sand over 100 square metres. Then to lay paddled clay mixed with hay (bhusa) in 10 cm thick layer giving a proper slope (1:40) to consolidate this layer. Plaster mud-phuska layer applied with mud-cow dung mortar (3:1). Finally tiles of terracotta to be laid on the above mentioned plastered surface to seal and grout joints in 1:3 cement mortar.

### 2.1.6 Madras Terrace:

Vernacular architecture of the south Indians roofs are sloped and projecting eaves combines the roofing system. But when flat roof structures or buildings with more than a floor needed to be built, this presented a complex predicament. Sometime during the colonial era, a new technique was pioneered from Madras to solve this problem called the 'Madras Terrace'. These are wooden rafters running along the shorter side of the rooms. Their bearing is the same as the depth of the beams, which usually is a bit more than 150mm. The wooden rafters of the sloped roof are translated in horizontal direction. The slab of brick and lime mortar are laid on these rafters. Three courses of diagonal brick course are laid with each course in alternate direction. Thus the slab ends up being very thick.

## 3.0 Vernacular Materials and Energy considerations for Roofing options:

Varieties of alternatives are available for the construction of roof of a building. Energy content and construction details of some of the roofing systems have been elaborate for construction of building in India. RCC slab is very commonly used for the floor slab as well as roof slab construction. RCC slab 10 $m^3$ of wet volume is considered for analysis. The total energy content of material constituting RCC slab is amounts to $12031.7\times10^3$ kcal for 100 $m^2$ of plan area or 10 $m^3$ of volume. Fig.A1 (Table-1) gives the energy content of seven options of roofing system. Energy/$m^3$ of roof as well as equivalent of RCC slab (1:2:4) of $10^3$ has been considered for comparative analysis

| Item | Description | Amount in Rs. | % of cost | 1000Xkcal | %Energy |
|---|---|---|---|---|---|
| Option1 | Conventional RCC | 24690.3 | 100.00 | 12031.07 | 100.00 |
| Option2 | Filler slab | 24152.89 | 97.82 | 11112.7 | 92.37 |
| Option3 | Reinforced Brick in | 21184.9 | 85.80 | 12001.5 | 99.75 |
| Option4 | Channel unit slab | 19250.3 | 77.97 | 9045.5 | 75.18 |
| Option5 | Cored Unit slab | 19623.3 | 79.48 | 10060.1 | 83.62 |
| Option6 | Jack arch roof | 37389.71 | 151.43 | 28408.14 | 236.12 |
| Option7 | Madras Terrace | 18018.27 | 72.98 | 18640.02 | 154.93 |

Table-1 Comparison energy and cost estimates for different options of roofing (100 $m^2$)

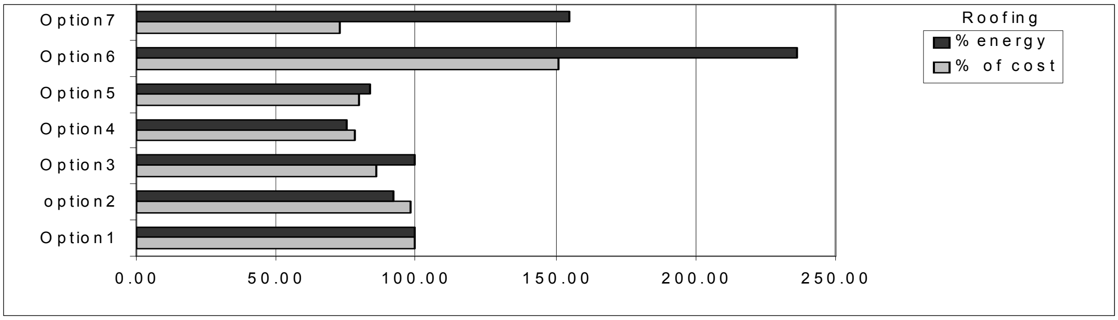


Fig.A1 Embodied Energy Vs cost estimate of roofing options

The energy content of the jack arch roof (option-6) is the highest with the value of $28408.4\times10^3$ kcal for 100 $m^2$ of roof area. The table-1 shows that the energy content of RS joist which is the major contributor of overall energy content. It is observed that embodied energy of channel unit slab and core unit slab show reduction of 25% and 16% respectively. The madras terrace roof is an economical solution but the energy content is 155% as compared to RCC slab. Filler slab consumes $11112.7\times10^3$ kcal for 100 $m^2$ this can further reduced to $10245.19\text{x}10^3$kcal per $100^2$ by replacing or avoiding filler material of terracotta tiles to mud block or less energy intensive materials. Channel unit slab is proved to be cost effective and less energy intensive option comparing to all.

## 3.0 Vernacular Materials and Energy considerations for Terracing options:

Table-2 shows the comparative analysis of different terracing options to the building in terms of embodied Energy and cost of terracing per 100 $m^2$ of terracing area. It can be determined from the comparative analysis (Table-2) Fig.A2 the lime concrete terracing is almost expensive in terms of cost as well as consumption of energy. As compared to lime concrete terracing the flat terracing, mud layer terracing and mud phuska terracing are shown reductions in the cost i.e. 63.2%, 62.22% and 64.78% respectively. And the energy consumptions are in the order of 28.5%, 20.20% and 23.74% as compared to lime concrete terracing respectively.

| Item | Description | Amount in Rs. | % of cost | 1000Xkcal | %energy |
|---|---|---|---|---|---|
| Option1 | Lime mortar terracing | 5526.82 | 22.10 | 10968.18 | 100.00 |
| Option2 | Flat Terracing | 15807.04 | 63.20 | 3126.04 | 28.50 |
| Option3 | Mud layer | 15561.98 | 62.22 | 2215.71 | 20.20 |
| Option4 | Mud phuska | 16201.76 | 64.78 | 2603.63 | 23.74 |
| Option5 | Lime concrete | 25011.91 | 100.00 | 10647.15 | 97.07 |
| Option6 | Pressed clay | 21209.40 | 84.80 | 5835.39 | 53.20 |
| Option7 | Cavity type | 24439.40 | 97.71 | 7940.94 | 72.40 |
| Option8 | Cavity lime concrete | 22948.48 | 91.75 | 6947.98 | 63.35 |

Table-2 Comparison of various terracing (100 $m^2$) options

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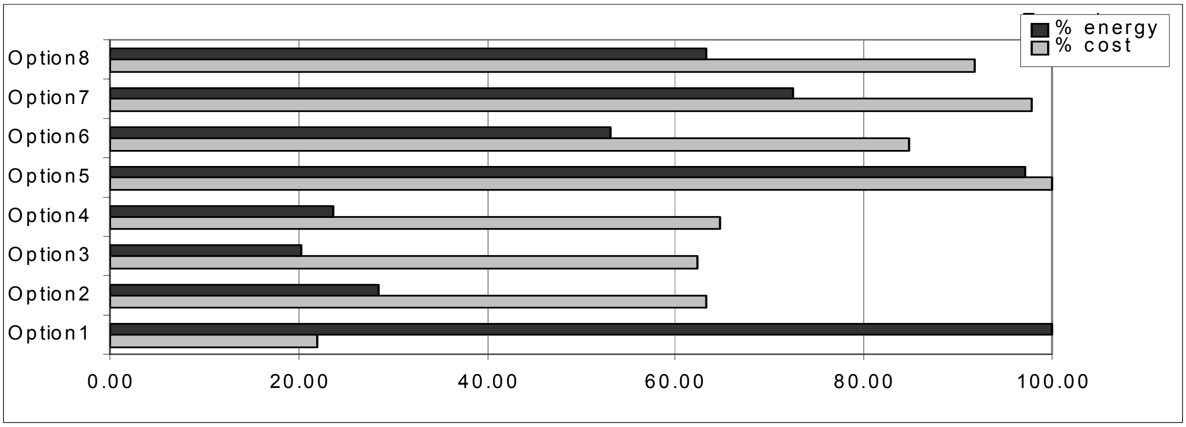


Fig. A2 Embodied Energy Vs cost estimate of terracing options

Table-2 shows, the cost of pressed clay, cavity type concrete are in the order of 84.80% and 91.75% with corresponding energy consumption of 53.20% and 63.35% respectively. Although the lime mortar terracing works out to more economical, but for the interest of energy conservation, it will be an expensive option for terracing as the brick ballast consume maximum energy in the order of 7957.02×$10^3$ kcal per 100 $m^2$

## 4.0 Conclusion:

Embodied energy in basic building materials of different types of roofing system and terracing and the cost estimate of buildings have been analyzed with respect to individual. The alternative technologies and less energy intensity materials brought convincing reductions in the energy content of the building materials independently. Energy estimation is mostly indicates that the energy content of the buildings is directly proportional to the cost estimation of buildings.

The studies illustrates that channel unit roofing, filler slab roofing, mud phuska terracing can bring down the embodied energy content considerably so as to conserve the energy in building Industry. Lesser embodied energy also contributes to make building cost effective. Even though the results are pertaining to Indian conditions, many other developing countries have similar construction practices, where these can be conveniently extrapolated and utilized to conserve the embodied energy with due consideration to the climate change and sustainable development. Energy efficient and vernacular materials is a new concept which deals with effective budgeting and following of techniques which help in reducing the cost of construction through the use of locally available materials along with improved skills and technology without sacrificing the strength, performance and life of the structure. There is huge misconception that low cost housing is suitable for only sub standard works and they are constructed by utilizing cheap building materials of low quality. The fact is that energy efficient construction is done by proper management of resources.

## References

[1] Alcorn. J. L, “Embodied Energy Analysis of New Zealand building materials – methods and results”. In ASGM seminar: Embodied Energy –The current state of play, Deakin university, 28-29 Nov,1996.

[2] Bansal, N.K and Cook Jeffrey: “sustainability through Building,” Omega Scientific publishers, India , 2001.

[3] Dutta B.N., ‘Estimating and costing’ 24th revised Ed , Rajkamal Electric press, Delhi , 2001.

[4] Reddy V. B.V, Jagadish, K. S., ‘Embodied Energy of common and alternative Building materials and technologies. ‘Energy and Buildings’ 35,129-137.2001.

[5] Reddy, V. B. V, Lokras. , S .S. ‘Steam cured stabilized soil blocks for masonry construction’, Energy and Building 29.pp29-33, 1998.

[6] Spiegel Rose, Meadows Dru., “Green Building Materials: A Guide to product selection and specifications”. John Wiley’s sons, Inc, 1999

[7]Mathur S. K, ‘Energy efficiency-Lifecycle cost of PVC building materials’, ‘Sustainability through building’ pp 85-91.,2001.

[8] Mohan Rai. ‘Energy conservation in production of building materials’ Energy and Habitat. Wiley eastern ltd, pp:63-65.,1984.

[9] Mullick A.K, ‘Proceeding on National workshop on Integrated Energy Management in Buildings’, Delhi, 1995.

[10] Walker P, Reddy, V B, Masbah A, Moral j. C, ‘The case for Compressed earth blocks construction’, Proceedings of 6th International seminar on structural Masonry for developing countries. Allied publisher Ltd., Bangalor India, pp: 27-35, October, 2000.

[11] Kofoworola, O.F & Gheewala S. H. “Life Cycle Energy Assessment of a Typical Office Building in Thailand.” Energy and Buildings, 41, pp.1076 – 1083.2009.

[12] Chel A. and G N Tiwari, ‘Thermal performance and embodied energy analysis of a passive house: Case study of vault roof mud-house in India’, ‘Applied Energy’. 86:1956-1969, 2009.